

What is claimed is:

1. A photonic crystal which comprises a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and said members additionally having randomly nanoporous surface porosity.
2. The photonic crystal of claim 1 wherein the members comprise spheres.
- 10 3. The photonic crystal of claim 1 wherein the members comprise spheres and the average sphere diameter does not exceed about 1000 nm.
- 15 4. The photonic crystal of claim 1 wherein the members comprise surfaces or interfaces that are inverse replicas of the surfaces of a monodispersed sphere array, wherein necks exists between neighboring spheres in said sphere array and the average sphere diameter does not exceed about 1000 nm.
- 20 5. The photonic crystal of claim 1 wherein the nanoporous surface porosity comprises nanopores having an average pore diameter which is less than about 10 nm.
6. The photonic crystal of claim 1 wherein the members comprise a semiconductor material.
- 25 7. The photonic crystal of claim 1 wherein the members comprise silicon.
8. The photonic crystal of claim 1 wherein the members comprise polysilicon.
- 30 9. The photonic crystal of claim 1 wherein the members comprise p type or n type doped silicon.

10. The photonic crystal of claim 1 wherein the members comprise p type or n type doped polysilicon.

5 11. A structure comprising the photonic crystal of claim 1 positioned on a surface of a substrate.

10 12. The structure of claim 11 wherein the substrate comprises a material selected from the group consisting of glass, quartz, borosilicate glass, silicon, sapphire and combinations thereof.

15 13. The structure of claim 11 wherein the substrate comprises sapphire.

20 14. The structure of claim 11 wherein the substrate comprises sapphire, which substrate is substantially flat, hydrophilic, HF resistant, optically transparent, and resistant to heat elongation in any direction at temperatures of up to about 800 °C.

25 15. The structure of claim 11 further comprising a device for alternately compressing and expanding the photonic crystal.

30 16. The structure of claim 11 further comprising a piezoelectric device for alternately compressing and expanding the photonic crystal.

25 17. The structure of claim 11 further comprising a liquid crystal material that is imbibed on the photonic crystal.

30 18. A process for forming a photonic crystal which comprises forming a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed

members having voids between adjacent members, and then providing surfaces of said members with randomly nanoporous surface porosity.

19. The process of claim 18 wherein the members comprise spheres.

5

20. The process of claim 18 wherein the members comprise spheres and the average sphere diameter does not exceed about 1000 nm.

10 21. The process of claim 18 wherein the members comprise surfaces or interfaces that are inverse replicas of the surfaces of a monodispersed sphere array, wherein necks exists between neighboring spheres in said sphere array and the average sphere diameter does not exceed about 1000 nm.

15 22. The process of claim 18 wherein the nanoporous surface porosity comprises nanopores having an average pore diameter which is less than about 10 nm.

23. The process of claim 18 wherein the members comprise a semiconductor material.

20

24. The process of claim 18 wherein the members comprise silicon.

25. The process of claim 18 wherein the members comprise polysilicon.

26 26. The process of claim 18 wherein the members comprise p type or n type doped silicon.

27. The process of claim 18 wherein the members comprise p type or n type doped polysilicon.

30

28. The process of claim 18 wherein the members are provided with randomly nanoporous surface porosity by chemical vapor etching, electrochemical etching or chemical stain etching.

5 29. The process of claim 18 wherein the members comprise silicon or polysilicon and the members are provided with randomly nanoporous surface porosity by chemical etching or electrochemical etching in an ethanolic HF solution.

10 30. The process of claim 18 wherein the photonic crystal is positioned on a surface of a substrate.

15 31. The process of claim 30 wherein the substrate comprises a material selected from the group consisting of glass, quartz, borosilicate glass, silicon, sapphire and combinations thereof.

32. The process of claim 18 further comprising contacting the photonic crystal with a device for alternately compressing and expanding the photonic crystal.

20 33. The process of claim 18 further comprising contacting the photonic crystal with a piezoelectric device for alternately compressing and expanding the photonic crystal.

25 34. The process of claim 18 further comprising imbibing a liquid crystal material on the photonic crystal.

35. A process for the formation of a three-dimensionally-periodic porous structure, comprising the steps of
(a) crystallizing spheres of material A into a first structure having three-dimensional periodicity, and voids between spheres, wherein the material A is

mechanically and thermally stable to at least about 600° C.,

(b) treating this first structure so that necks are formed between the spheres of material A,

(c) infiltrating said first structure with material B to form a A-B composite structure,

5 (d) removing material A from said A-B composite structure to form a second structure comprising material B; and then

e) providing surface of said second structure with randomly nanoporous surface porosity.

10

36. A process for preparing a three-dimensionally-periodic, porous, dielectric, photonic crystalline structure which comprises forming an array of microscopic spheres on a smooth substrate into a face centered cubic structure having spaces between adjacent spheres, which spheres have an average

15 diameter not exceeding about 1000 nm; sintering the spheres under conditions sufficient to attach adjacent spheres to one another by an intermediate neck; forming a solid silicon structure in the spaces between adjacent spheres by infiltrating silane gas into the spaces in a low pressure chemical vapor deposition process; wherein the silane gas is infiltrated into the spaces at a

20 temperature of from about 450 °C to about 600 °C, at a pressure of from about 100 mtorr to about 600 mtorr and at a flow rate of from about 50 sccm/min. to about 150 sccm/min.; removing the spheres; and then providing surface of said structure with randomly nanoporous surface porosity.

25

37. The process of claim 36, wherein the opal template in step (a) consists of silica (SiO₂) spheres of diameter from about 100 nm to about 1000 nm.

38. The process of claim 36 wherein the nanoporous surface porosity comprises nanopores having an average pore diameter which is less than about 10 nm.

39. The process of claim 36, wherein the spheres are surface coated with material a layer of a metal at a thickness of from about 0.1 nm to about 50 nm.

5 40. The process of claim 39 wherein the metal comprises aluminum, gold, silver, platinum, or combinations thereof.

10 41. The process of claim 36, further comprising infiltrating an additional material into the structure in the spaces between adjacent spheres before the removal of the spheres to form a composite structure.

15 43. The process of claim 41 wherein the additional material is selected from the group consisting of thermoelectrics, ferroelectrics, ferromagnets, metals, semimetals, elastomers, polymers and combinations thereof.

20 44. The process of claim 41, wherein the additional material comprises carbon, chalcogenide glasses, tin, lead or combinations thereof.

25 45. A photonic device which comprises a photonic crystal which comprises a two dimensionally periodic or three dimensionally periodic microporous structural matrix of interconnecting, crystallographically oriented, monodispersed members having voids between adjacent members, and said members additionally having randomly nanoporous surface porosity; and an electrically conductive, optically transparent layer positioned on opposite surfaces of the photonic crystal.

30 46. The photonic device of claim 45 wherein the electrically conductive, optically transparent layers are electrodeposited on the opposite surfaces of the photonic crystal.

47. The photonic device of claim 45 further comprising an electrode attached to the electrically conductive, optically transparent layers.

48. The photonic device of claim 45 further comprising a light emitter positioned to direct light onto the photonic crystal.

5

49. The photonic device of claim 45 further comprising a light emitter positioned to direct light onto the photonic crystal which is capable of transmitting light having a wavelength in the range of from about 1300 to

10 about 1600 nm.